NVIS Antennas for short skip (hops)

Background and Theory:

High Frequency (HF) signals below 50 MHz are capable of being reflected off the F layer of the ionosphere if the ionosphere density is sufficiently ionized. The density is commonly (simplified) measured as “solar flux”, which fluctuates accordingly to daytime/night daily cycles, season cycles, and the eleven-year sunspot cycle. At high points of the solar cycle, the F layer of the ionosphere is highly reflective (dense) while the opposite is true at the sunspot cycle troughs (low refractivity levels). The more ionization in the F layer, the better when using HF. However, it’s not possible to avoid over-simplification, as there are many other factors that affect the shape and changing densities of the ionosphere.

NVIS is the acronym for Near Vertical Incidence Skywave, which translates as an antenna system designed to maximize radiation and reception as close as possible directly above one’s location. This is also called maximizing for “short skip”

Signals are thus directed straight upward toward the overhead F layer of the ionosphere above us. The idea is that the ionosphere will act like a giant reflector (like a repeater) and shoot the signal straight down. This Sky reflector, populated by ions activated by the sun, is located between 150 km (93 mi) to 500 km (310 mi) above the surface of the earth.

Simplified, stations within a line of sight of this same point (reflector in the sky) can communicate reliably in practical terms, with stations located within 500 miles (plus or minus) of each other, **depending. . .** on time of day, season, and sunspot cycle. This is also called a single hop situation.

Through hands-on experience throughout a sunspot cycle, during different times of the day, and all four seasons a HF operator obtains direct knowledge of how these factors combine. Foremost, there must be a sufficient amount of ionization in the F layer or else the radio signals will pass through into outer space and not be reflected back down to earth.

Long distance communication (DX) depends on the opposite radiation pattern and conditions, i.e., Near Horizontal Incidence Skywave (NHIS). Instead of shooting the signal straight up, one maximizes the signal toward the horizon (using low angle radiators). Simplified, if we visualize the ionosphere as being a layer of evenly dense ions, we can visualize that the reflective angle of incidence will govern the reflective angle reflection outward. We can also see how the lower angle of incidence will hit more ions because of its angle than a signal sent straight up perpendicular to the F layer, which explains why when the ionosphere is weak, short distance communications suffer more than long distance communications. Vertical antennas, for example, are low angle radiators, good for ground wave and DX, but deficient in vertical incidence skywave propagation. Vertical antennas also tend to pick up more noise (QRN).

The D layer of the ionosphere (located directly below the F layer, absorb lower frequency RF, especially so on 160m, 80m, and 60m during the day. At night the D layer disappears allowing longer distance communication. Despite D layer absorption on 80 meters and 160 meters during the day, 80 meter communications during the day is still reliable within 300 miles (1 hop) anytime in the solar cycle or season, but stations need to have low ambient noise levels (low QRN). At night, the D layer absorption of signals dissolves and allows better communication. NVIS is good for one or two hops. Each bounce increases the loss.

The second hop is the reflection by the earth or body of water that bounces the signal back up again to the ionosphere. The second hop is greatly attenuated with exceptions being over salt water or highly conductive ground. Especially during the daytime, D layer absorption can be said to double the loss at each additional hop on 160m and 80m.

Practical NVIS Antenna Design

For our needs to hop over the East Bay hills to reliably communicate with the County Seat in Martinez, Sacramento, or other parts of Contra Costa County, we need to maximize the signal straight up (near vertical). For that purpose, vertical antennas are the worse choice, because they radiate broadside to their vertical section and tend to null the signal directly above and below it. Besides desiring a horizontal antenna, we want a low angle radiation pattern where the earth will help reflect the signal straight up (the opposite of DX antenna design).

As we know a standard ½ wave dipole antenna (125' long for 75m) will need to be ½ wavelength above a perfect ground to generate a reasonable horizontal component (low angle incidence). Although, we know that there is no such thing as perfect ground and there are always some objects near the antenna that influences its tuning, but we take this as our starting point.

In order to direct the radiation toward near vertical (straight up), we need to lower the dipole to less than ½ wavelength above the earth, but not too low. Any distance below ¼ wavelength above the ground will produce significant vertical radiation, but also will induce ground loss. A ¼ wavelength height above ground on 80m is below 62 feet above ground. At 62' above ground, which should be very easy to obtain, you will obtain significant NVIS, given that a half wave is 125'

To obtain NVIS, simply avoid going above ¼ wavelength above ground. You are all set with a dipole lower than 62' for 75m operation. For 60m, 45' maximum and for 40m, 33' (1/4 wavelength) would be the maximum height for good NVIS..

But don't go too low. Many of the NVIS articles mistakenly suggest the idea of "the lower the better". Such is ill advised, because of ground losses and safety issues. Any distance lower than 1/8th wavelength above ground is not only excessive, but detrimental due to lossiness and detuning.

Therefore, a 75m dipole (120' long) not higher than 62 ft above ground should serve nicely for NVIS for 80m. If you are running 100 watts, the wire can be made with 18-gauge copper stranded wire (#16 or #14 AWG is better but heavier). For considerably less RF noise (ambient RF noise is a too common problem, do not use coax if you can avoid it,. Use ladder line to a tuner instead. That antenna and tuner will also operate very well on 60m, 40m, 30m, 20m, 17m, 15m, 12m, 10m, and 6m.

There are 3 or 4 standard dipole and wire configurations.
1. **Standard Dipole** center fed with both ends and feed-point in a straight line.
2. A **sloper**: A dipole with one end higher than the other end.
3. An **inverted Vee**: The apex (feed point) are the located at the high spot and the two ends are lower (closer to the ground).
4. An **inverted L**: Similar to the inverted Vee, but imbalanced.
5. A **vertical**: A vertical can be considered to be a vertical dipole with one end cut off and replaced with radials. It notoriously needs many radials to work well. It is a low angle radiator and has little vertical incidence. Since ¼ wave vertical on 75m is 62' they are usually coil loaded, hence suffer from coil loss and low Q.
6.End **fed wire**. It is like a vertical, but strung out diagonally or horizontally. It requires a good ground plane or radial system.
7. Off Center fed dipole (**OCFD**): Not recommended because of the tendency to pick up RF noise and coax loss.
8. **G5RV** all band dipole.
8. See **ALE** antennas below.
9. A **horizontal (full wave) quad** loop

D layer absorption

During the daytime the D layer is active which attenuates the radio signals moving toward the F layer. Despite D layer attenuation signals still get through, but communication is better usually at night. Because the F layer thins out at night, longer distance communications become easier because the increase in the angle of incidence (distance) experiences more ions. Close-in stations may need relays from more distant stations if there is not enough ionized ions, which happens at sunspot cycle lows. We are finally entering into Sunspot Cycle 25 which will provide much more reliable skip conditions than experienced the past.

Reducing Ambient Noise: Static

You can also run coax straight from the center feed-point of the antenna to the radio, but you will experience loss in the coax at any frequency except the tuned frequency. The antenna will also be subject to increased ambient RF noise plus common mode loss. Common mode noise can be reduced by using common mode filters (see footnotes).

Open wire transmission line or ladder line will lower your noise floor when compared with coax and is generally less lossy.

Vertical antennas are infamous for picking up stray ambient noise (static). They are very poor NVIS radiators while tending to generate near horizontal ground wave (good for DX). In many locations, noise levels can be as high as S9. Such can be considerably reduced.

ALE (Automatic Link Establishment) antennas accentuate unwanted ambient noise. They are used for spread spectrum like security comms and other encoded automatic frequency and band hopping radio comms for security purposes thus they are designed for broad-band and all-band use. Therefore, they can increase the pickup of stray RF across the radio spectrum, thus being labelled noisy. On the low bands, such as 80m and 60m the noise floor may be a major limitation.

Magnetic loop antennas are very quiet receivers, but not necessarily the best transmitting radiator. Delta and Quad loops (full wavelength long) fed by open wire or ladder line are quiet and make an excellent choice if your location lends itself to such.

In general, verticals, end fed antennas, and unbalanced antennas (Off Center Fed) may pick up more unwanted ambient noise than desired (QRN).

Summary

An easy solution is to construct a simple dipole 125' long (two 62.5' sections) fed at the center with ladder line. Use the longer number if you have room, either as a dipole, an inverted Vee, or a sloper. Use # 16 gauge or thicker gauge wire (#14AWG or #12 AWG). Run the ladder line directly into an antenna tuner that accepts ladder line. If ladder line is impractical, then run the ladder line to an outdoor balun, and then run high quality coax from there to the tuner as close to the transceiver as possible (the shorter, the better).

Here is a high-power balun capable of handling 1 KW where the ladder line connects on an exterior wall and then you can run coax inside the house. https://www.balundesigns.com/model-1171-1-1-atu-current-balun-1-54-mhz-5kw/

Running the ladder line straight to the antenna tuner, and a short run of coax to the radio is ideal.

Common Mode Filters

From an excellent article on Common Mode Noise from Balun Designs:

"Noise generated by common mode currents which can be induced on the shield of a coax feedline if it is exposed to strong RF such as those from a nearby high power AM station.

The shield is also subject to common mode if it runs close to or through electrical fields created by AC lines in your home or electrical equipment (like switching power supplies) located in close proximity to the feedline. Common mode that distorts your audio creates "mic bite" occurs when the coax feedline passes through the radiated RF near field from your antenna. Common mode currents can also be created by a large impedance mismatch at the feedpoint of an antenna. It should be noted this is only an issue when coax is being used and not with open wire or ladder line feedlines.

The good news is that high quality 1:1 baluns (aka feedline, isolation and or choke baluns) can usually eliminate this type of noise or RFI when installed in the feedline close to your equipment. Note the term "high quality" which means if you think the price is a good deal, the chances are the balun is not! Additionally, having one installed at or near the feedpoint of your antenna is not only beneficial to your transmitted signal, but can also be a first line of defense in the war against noise. This type of balun should generate high levels of choking impedance on the bands where the noise is the is most noticeable while having negligible insertion loss to any incoming signal.

Balun Designs:
Common Noise Sources: https://www.balundesigns.com/reference/noise-sources-rfi-and-their-suppression/

An excellent article on open wire or ladder line balun selection from Balun Designs: https://www.balundesigns.com/blog/baluns-for-multiband-antennas-fed-with-open-wire-or-ladder-line/

Common Mode Noise Suppression Baluns https://www.balundesigns.com/feedline-isolation-baluns/

An article in QST Magazine by Joel Hallas, W1ZR on eliminating HF Noise: https://www.balundesigns.com/content/RFI.pdf

Palomar Engineers https://palomar-engineers.com/rfiemi-solutions/common-mode-noise-coax-filter/Coax-Common-Mode-Noise-Filter-c21444130

Palomar Engineers Common Mode Chokes https://palomar-engineers.com/antenna-products/1-1-balun-kits

Palomar Engineers Coax Noise Filters https://palomar-engineers.com/ferrite-application-experts-2/Coax-Noise-Filters-c24774281

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